

# Development Performance of Beam Dump

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**Abstract** – A 10 MeV, 10KW s-band (2856MHz) electron Linear Accelerator (LINAC) is proposed to developed for irradiation applications at Raja Ramanna Centre for Advanced Technology, Indore. The accelerating structure is a  $2\pi/3$  constant impedance travelling wave structure, designed accelerators 50 KeV electron beam from the electron gun to 10 MeV. It comprises of travelling wave buncher cells followed by accelerating cells. A beam dump is absorbing the electron beam and X-ray coming out of the LINAC. This paper presents an improved design for the existing beam dump of this accelerator. The new design is moved efficient, safer, economical and compact than the previous design.

1. Here investigated both for maximum stress and maximum temperature. The material selection is done keeping in mind the radiation damage, thermal conductivity, corrosion in the ozone environment, mechanical strength and manufacturability. The estimated maximum temperature is 55°C which is less than boiling point of water 0.2 bar pressure (60.1°C).

2. The Maximum stress intensity is estimated to 29.52 N/mm<sup>2</sup> / which is less than the yield strength (207N/mm<sup>2</sup>) of the material.

**Keywords** –Material selection, Shape selection, Structural design, Stress analysis, Deflection analysis, Thermal design, Temperature calculation & analysis, Mass flow rate.

## 1. INTRODUCTION

The beam dump is to safely absorb a beam of charged particles such as electrons, protons, nuclei or ions. This is necessary when a particle accelerator has to be shut down. Dealing with the heat deposited can be an issue, Since the powers of the beams to be absorbed can run into the megawatts.

It consist of an Aluminium rectangular box 400mm x 50mm rectangle having five square hole having 20mm x 20mm. A 12 thick and 150mm wide plate is attached to this rectangle. This plate has the heat flux incident on it.

The water (LCW) at high pressure 6 bars is forced through the channels to remove heat by convection. We have used a parallel flow. Due to high pressure making the structure prone to deflections. Also due to high temperatures, warping is also induced in the beam dump. Therefore the beam is to be designed for the structural and thermal loads acting on it. As a result, the analysis is divided into two parts structural and thermal.

## 2. DESIGN PARAMETERS

Aluminum 5086 alloy is the material selected for the beam dump as it has relatively lower conductivity that facilitates easy machined and easy welding during fabrication and also because its activation energy is greater than 10MeV. The threshold energy for  $\gamma$ -n radiation in Aluminum is 13MeV. The scanned electron beam held has approximate size 150mm x 1000mm at the location of beam dump. Therefore the beam dump consist of 400mm x 1500mm rectangular box having five square channels each of dimensions 20mm x 20mm inscribed on it. A 150mm x 1368mm

x 12mm cover plate is attached to this box. This plate has all the heat energy of the LINAC incident on it.

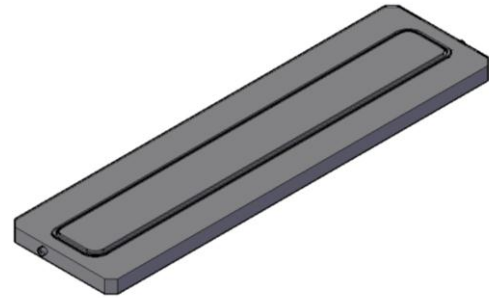


Table: 1  
Properties of Aluminum 5086 alloy.

Property	Value
Specific heat	896 KJ/Kg-.K
Thermal conductivity	0.121W/mm K
Young's modulus	72,000 M/mm <sup>2</sup>
Coefficient of thermal expansion	23.8 x 10 <sup>-6</sup> /K
Poisson's ratio	0.33
Yield strength	207 N/mm <sup>2</sup>

## 3. THERMAL ANALYSIS

LINAC produces 10 KW heat energy that is incident on the beam dump generating an average heat flux 0.0487 W/mm<sup>2</sup> over the surface of the cover plate. The reference temperature is assume to be 30 °C and volume flow rate of 20 litre per minute (lpm) is applied. A very high volume flow rate is not desirable as it will increase fluid velocity resulting in higher rates of erosion.

## 4. CALCULATION

The forced convection occurs in the channels and since this value of convection coefficient is entered as input data for the software Ansys workbench14, its value is to be calculated manually.

It is assume that the inlet water temperature is 30 °C. and the ambient air temperature is 30 °C. For the volume flow rate of 20 lpm (3.33 x 10<sup>-4</sup> m<sup>3</sup>/s), and the channel area of (20mm x 20mm), the fluid velocity of 0.833 m/s is obtained.

Thus, by using the various property of water from Table 2, a mass flow rate of 0.33 Kg/s is obtained. Using the above values in Equation (1), We get the change in water temperature as 7.25 °C.

$$Q = mc \Delta T \quad (1)$$

The bulk mean temperature of water is calculated as 33.625 °C. from the Equation (2). Using the property value of water at 34 °C. from Table 3, the Reynolds Number [Equation(3)] comes out to be 22,392, making the flow turbulent.

$$T_b = T_{wi} + \Delta T/2 \quad (2)$$

$$Re = v D / \nu \quad (3)$$

The Dittus – Boelter correlation, Equation (4), along with the values from Table 3, gives the value of forced convection coefficient (h) as 4103.04 w/ m<sup>2</sup> K.

$$Nu_d = 0.023 \times Re^{0.8} \times Pr^{0.4} \quad (4)$$

#### 4.1 MODELING

Since a 3D analysis is performed, the beam dump is modeled as 1500mm x 400mm x 50mm rectangle block having five square holes having dimensions 20mm x 20mm. A 12mm thick and 1368mm length x 150mm wide plate is attached to this rectangle block which has the heat flux incident on it.

Table: 2  
 Properties of water at 30 °c.

$\rho$	997.5 Kg/m <sup>3</sup>
C	4178 J/Kg K

We have assumed a uniform heat flux distributed on the top plate of the beam dump. The heat flux incident on plate is 0.0487 W/mm<sup>2</sup>.

#### 4.2 RESULTS

The temperature contour due to the incident flux is shown in Fig 3. The maximum temperature is estimated to be about 55 °c. in Fig 4. The total rise in temperature of water is about 7.25 °c.

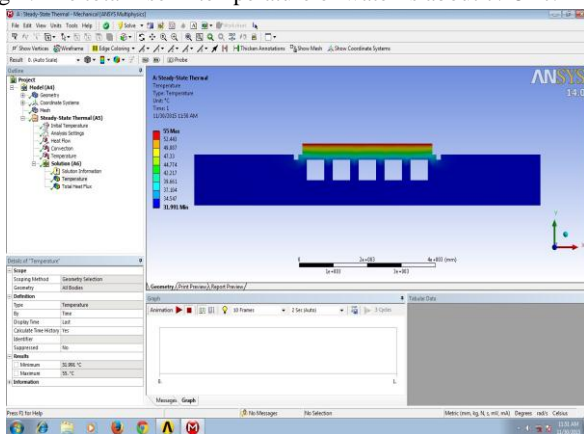


Fig. 3. Temperature contour of beam dump.

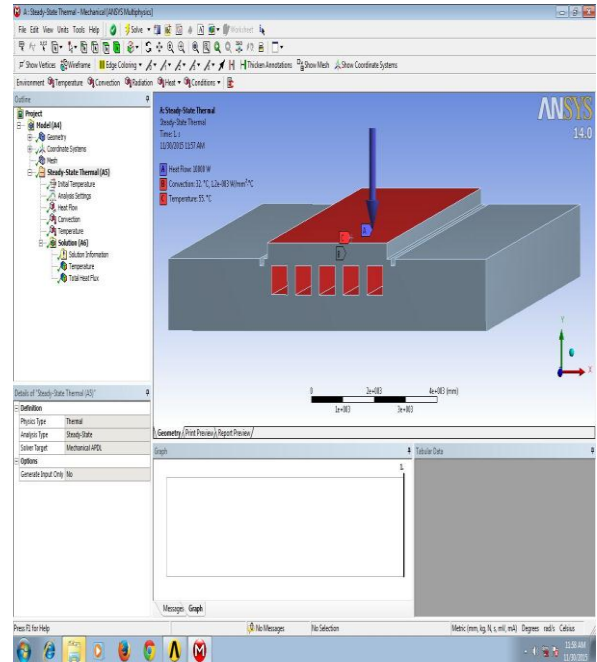


Fig 4. Temperature of beam dump after incident 10 KW heat

### 5. STRUCTURAL ANALYSIS

For the purpose of structural analysis the modeling is same as that for the thermal analysis. The water is pumped at the pressure of 6 bar exerting a pressure of 6 bar on the inside walls of the cooling channels.

Table: 3  
 Properties of water at 34 °c.

$\rho$	996.25 kg/m <sup>3</sup>	P	5.01
$\theta$	0.744x10 <sup>-6</sup> m <sup>2</sup> /s	K	0.62 w/m k
c	4178J/kg k	V	0.833m/s

A uniform pressure of 0.6 N/mm<sup>2</sup> (6bar) is applied on the lines of all the 5 square holes of the rectangle indicating that the pressure of water is constant throughout the flow, however, the pressure drop due to friction between inlet and exist was neglected as its value is about 180 mbar.

#### 5.1 RESULTS

Deflection contour and stress intensity contour due to temperature rise and water pressure are shown in Fig.5, and Fig. 6. The maximum deflection of 0.078mm and maximum stress intensity of 29.526 n/mm<sup>2</sup> is observed in beam dump due to thermal distortion and water pressure.

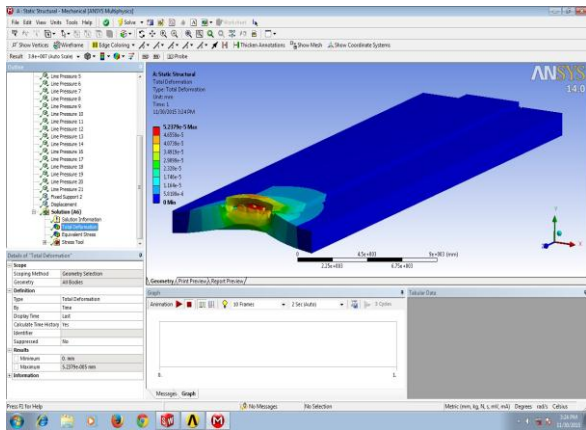


Fig.5. Analysis of Deflection

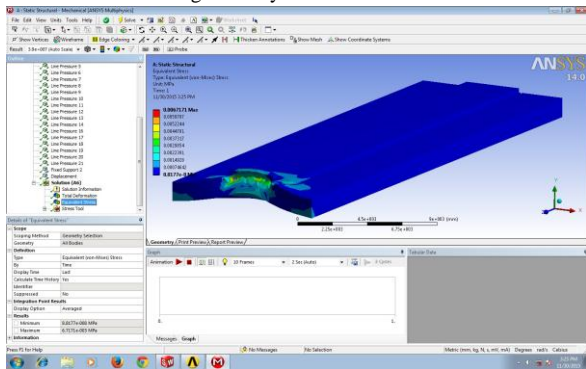


Fig. 6. Stress intensity of beam dump

### 6. DISCUSSION AND CONCLUSION

The maximum temperature is attained at the top surface of the cover plate. This does not create any problem as it is still less than the boiling point of water. Boiling of water inside the channels is highly undesirable as it will increase the pressure inside and beam dump may crack or even burst.

The design is more efficient as far as heat removal is concerned. Due to the 5 channels remove the same quantity of heat as the temperature and other properties of water are same in all the channels.

The maximum deflection of the top plate is less (0.078717mm). It is acceptable range. The stress intensity in design is very less (29.526) than the yield strength of the material. Thus the beam dump is safe as far as yielding due to water pressure is concerned.

### APPENDIX

Q	Heat transfer rate
m	Mass flow rate
C	Specific heat capacity
D	Hydraulic diameter
$\nu$	Kinematic viscosity
Nu	Nusselt number
$T_b$	Bulk mean temperature
$T_\infty$	Ambient temperature
$T_{wi}$	Inlet water temperature
$T_{oi}$	Outlet water temperature
K	Thermal conductivity
Pr	Prandtl number
$T_w$	Wall temperature
$T_f$	Film temperature
Re	Reynolds number
Gr	Grashof number

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